Assessing the role of land surface hydrology in the development of terrain-induced convection

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Thermally-forced terrain circulations...

Images courtesy Zardi and Whiteman, 2012
Background: Terrain circulations...

- Formalization:

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial s} + w \frac{\partial u}{\partial n} = - \frac{1}{\rho_0} \frac{\partial (p - p_a)}{\partial s} - g \frac{d}{\theta_0} \sin \alpha - \frac{\partial u'w'}{\partial n}
\]

\[
\frac{\partial w}{\partial t} + u \frac{\partial w}{\partial s} + w \frac{\partial w}{\partial n} = - \frac{1}{\rho_0} \frac{\partial (p - p_a)}{\partial n} + g \frac{d}{\theta_0} \cos \alpha
\]

\[
\frac{\partial \theta}{\partial t} + u \frac{\partial \theta}{\partial s} + w \frac{\partial \theta}{\partial n} = - \frac{1}{\rho_0 c_p} \frac{\partial R}{\partial n} - \frac{\partial w' \theta'}{\partial n}
\]

\[
\frac{\partial u}{\partial s} + \frac{\partial w}{\partial n} = 0
\]

Local Press. Perturbation
Buoyancy-reduced Gravity

Sensible Heat Production

Gochis et al., VAMOS Modeling Workshop, Petropolis Brazil 2012
Questions and Hypotheses:

1. How do the ‘super-position’ of sfc energy fluxes influence on thermal circulation regimes…

   - Background circulation

   How does uncertainty in antecedent precipitation and land surface flux partitioning impact convective activity in subsequent NAM forecasts?

   - Suppressed circulation (wet/snow peaks)

2. What role does ‘landscape-scale’ hydrology have on modulating surface fluxes?
Motivation:
Motivation:
Experimental Design:

Goals:

1. Diagnose controls on land-sfc-fluxes
2. Assess impact of local fluxes on PBL-CI behavior (model-based)
3. Define the role of land-sfc fluxes on multi-day forecasts
Experimental Design:

1. 1-d land surface model studies on model forcings

2. 3-d WRF diurnal cycle initialization experiments
Offline evaluation of Noah LSM Surface Fluxes:

Sensible vs. Latent Heat Flux Partitioning - Rayon Tower Site July, 2004

Gochis et al., VAMOS Modeling Workshop, Petropolis Brazil 2012
Offline evaluation of Noah LSM Surface Fluxes:

Soil Temperature - Rayon Tower Site July, 2004

Soil Moisture - Rayon Tower Site July, 2004

Skin Temperature - Rayon Tower Site July, 2004
Coupled WRF Model Configuration & Experiments:

- Dates: 1 Diurnal Evolution… 12-24z Jul. 15, 2004
  - ‘Typical’ monsoon day following ‘active’ period but no significant dynamical forcing

- Configuration:
  - Single 1km domain, NARR Init./L.B.C
  - No Cu-Parm, YSU-PBL, M-O Sfc. Layer, Thompson Microphys.
  - Slab & Noah-LSM

- Initializations:
  - Slab model – Water availability factor as f(Landuse)
  - North American Regional Reanalysis
  - 18month HRLDAS driven by NLDAS2 (w/out routing extensions)
Land Surface Spin-up/Initialization Evaluation: 1200z

- Soil Moisture
- Soil Temperature
- Skin Temperature

NARR Init

NOAH_NORT
WRF Model Evaluation: by 1900z

Noah-NARR init.

Noah-HRLDAS init.
SENSIBLE
HEAT
FLUX (19z)

Noah-NARR init.
Noah-HRLDAS init.
LATENT HEAT FLUX (19z)

Evaporative Fraction (19z)

PBL
HEIGHT
(19z)

Noah-NARR init.

Noah-HRLDAS init.
WRF Model Evaluation: by 1900z

Noah-NARR init.  
Noah-HRLDAS init.
Conclusions:

- Land model structure and initialization has pronounced influence diurnal evolution of surface fluxes, PBL growth, and clouds in the N. Am. Mon.:
  - Dry/hot Noah-HRLDAS shows high H and low LH w/ little cloud (pos. ‘dry’ feedback)
  - Moderate NARR init. produces comparatively greater sensible heat flux heterogeneity, greater PBL height variability and more cloud (‘mixed’ regime)

- Biases in precip. analyses used in data assimilation may play a critical role in limiting prediction skill

- In regions and flow regimes where coupling is ‘strong’ the findings suggest it is important to properly capture local energy partitioning